Science Entry Competencies

A. Natural Sciences General Entry Competencies

I. Quantitative skills

Students are more likely to succeed in a college science course if they enter with adequate preparation in mathematics. Students are strongly encouraged to meet the entry-level standards described for college math before enrolling in an introductory college-level science course.

II. Scientific Inquiry

1) Science understanding is developed through the use of scientific investigation, reasoning, and critical thinking.
   a) Scientific inquiry requires the ability to gather and analyze information and ideas.
      i) Apply sound library research skills (e.g., article searches, online databases).
      ii) Evaluate a given source for its scientific credibility (e.g. web sites, product advertisements, use of personal testimony in place of scientific evidence, etc.).
      iii) Read with comprehension and be able to summarize and draw conclusions from written material in basic science.
      iv) Interpret data using various representations (e.g., graphs, tables, charts, and plots).
   b) Scientific inquiry includes the ability to formulate a testable question and explanation.
      i) Compose testable questions and hypotheses.
      ii) Differentiate between a hypothesis and a scientific theory (e.g. a hypothesis is a tentative but testable explanation subject to experimentation; a scientific theory has been repeatedly confirmed through observation and experimentation).
      iii) Design and conduct a valid experiment (formulate and clarify the method; identify the controls; collect, organize, display and interpret the data; make revisions of hypotheses, methods and explanations; present the results; and seek critiques from others).
      iv) Recognize that it is not always possible, for practical or ethical reasons, to control some conditions (e.g., when sampling or testing humans, when observing animal behavior in nature).
      v) Acknowledge there is no fixed procedure called "the scientific method," but that some investigations involve systematic observations, models (e.g. astronomy), carefully collected and relevant evidence, and logical reasoning in developing hypotheses and other explanations.
   c) Scientific inquiry includes the ability to select and utilize appropriate investigative methods and tools to gather and interpret relevant data.
      i) Make qualitative and quantitative observations using the appropriate senses, tools and equipment to gather data (e.g., microscopes, thermometers, computers, balances, metric rulers, graduated cylinders).

ii) Measure length to the nearest millimeter, mass to the nearest gram, volume to the nearest milliliter, temperature to the nearest degree Celsius, time to the nearest second.
iii) Understand the metric system and perform simple conversions within the metric system and between the metric and US systems. Use and interpret values written in scientific notation (exponents).
iv) Judge whether measurements and computations of quantities are reasonable.
v) Calculate descriptive statistics (e.g. mean, median, mode, range, ratio, percentage).
vi) Depict data using various representations (e.g., graphs, tables, charts, and plots).

d) Scientific inquiry includes the evaluation of scientific principles and explanations (laws, theories, models) as well as the methods used to support them.
i) Analyze whether evidence (data) and scientific principles support proposed explanations.
ii) Communicate and defend a scientific argument.

2) A scientific theory is an explanation of some phenomenon of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment.
a) Scientific explanations of phenomena change over time as a result of new evidence (e.g., cell theory, theories of spontaneous generation, theories of extinction, evolutionary theory, genetic theory of inheritance).
i) Differentiate between scientific theories and laws. In science, a law is a description of a specific relationship among observable phenomena (e.g., the Gas Laws), but does not explain the observed relationship. A theory explains a set of laws and related phenomena (e.g. the theory of plate tectonics explains diverse observations regarding the distributions of volcanoes, earthquakes, and geological formations, as well as the relationships among organisms that inhabit different continents). Theories lead to new predictions and tests of those predictions.
ii) Explain why accurate recordkeeping, openness, and replication are essential for maintaining an investigator's credibility with other scientists and society.
iii) Recognize that acceptable validation of scientific theories includes reproduction of results and clearly reported methods and procedures that increase the opportunity for further research.

b) Knowledge is cumulative and learning requires retention of knowledge and application to further topics; knowledge gained in one science is applicable to other sciences.

3) Science and technology affect, and are affected by, society.
a) Science and society interact to determine the direction of scientific and technological progress.
i) Understand that social and economic forces strongly influence which science and technology programs are pursued and supported with investment of resources and manpower.
ii) Recognize the role of science in both personal and public decision-making.

iii) Be able to evaluate scientific issues that impact your daily life.

b) Science advances through the development and application of new technology and new ideas.
   i) Realize that technological challenges may create a demand for new science technology.
   ii) Understand that new technologies make it possible for scientists to extend research and advance knowledge.

B. Life Sciences Entry Competencies

These competencies define the knowledge and skills needed for students to successfully enter and complete college-level work in biology. Sources used in preparation of this document include 1) Updated draft of Course Level Expectations in Science prepared by Missouri DESE 2) Quality in Undergraduate Education (Georgia State University Proposed Standards for Non-Majors Biology Course) 3) Natural Sciences, A Project of AAU and Pew Charitable Trusts 4) MoDEC entry-level skills recommendations in reading, writing and math and 5) ACT College Readiness Standards.

The purpose of high school biology is to help students develop a foundation in biology that focuses on major themes in the discipline, and to help them become scientifically literate citizens. For example, students need to be familiar with health-related issues, biotechnology and agriculture issues, environmental concerns, and the human impact on natural systems. Of equal importance is that students understand the nature of scientific endeavors. The recommendations in this document highlight major themes and concepts in the discipline. Towards this end we encourage emphasis be placed on why biological processes (e.g. mitosis, photosynthesis, respiration, etc.) are important and less emphasis be placed on the details of these processes. We also encourage a shift in the emphasis from cell and molecular biology to a more balanced approach that includes organismal, evolutionary and ecological biology.

I. Properties and Principles of Matter and Energy

1) Matter is composed of atoms that enter into chemical reactions to form molecules.
   a) Cells carry out chemical transformations for the synthesis or breakdown of organic compounds.
      i) Identify reactants and products in a chemical equation.
      ii) Understand the importance of the water molecule and the carbon atom to living organisms.
      iii) Identify the major organic compounds (proteins, nucleic acids, lipids, carbohydrates) that are found in living systems and identify their dietary sources.
   b) Enzymes are chemicals that facilitate the breakdown and synthesis of molecules in living organisms.

2) Energy for most living organisms is derived ultimately from the sun.
   a) Energy from the sun is converted to ATP within living organisms.
      i) Understand that energy is stored or released in the breakdown and/or synthesis of organic compounds.

ii) Recognize that as energy is transformed from one form to another (e.g., metabolic pathways, food webs), the amount of usable energy decreases with each transformation.

b) ATP is used by all organisms as a source of energy to do work in a cell.

II. Characteristics of Living Organisms

1) Cells are the fundamental units of structure and function of all living things.
   a) All cells share basic features (e.g., a plasma membrane).
      i) Explain the characteristics that separate living cells from non-living matter (e.g. reproduction, metabolism).
      ii) Recognize that all organisms are composed of cells, the fundamental units of structure and function; organisms may be unicellular or multicellular.
      iii) Describe the structure of the plasma membrane and the function of the following cell components: plasma membrane, cell wall, cytoplasm, nucleus, chloroplast, mitochondrion, and ribosome.
      iv) Predict the movement of molecules across the plasma membrane (i.e. diffusion, osmosis, active transport) as cells exchange materials with their environment or with other cells.
   b) Different types of cells have different specializations.
      i) State the similarities and differences between the cells of prokaryotes and eukaryotes, and plants and animals.
      ii) Recognize that cells both increase in number and differentiate, becoming specialized in structure and function, during and after embryonic development.

2) Living organisms transform energy through the processes of photosynthesis and cellular respiration.
   a) Photosynthesis and cellular respiration are complementary processes necessary for the survival of most organisms on Earth.
      i) Compare and contrast the function of mitochondria and chloroplasts (know that mitochondria are responsible for converting energy from food to usable ATP and that chloroplasts harvest energy and carbon from the sun and air, respectively).
      ii) Compare and contrast the products and reactants for the overall processes of photosynthesis and cellular respiration, stressing the importance of and the interrelationship between these processes (e.g., recycling of oxygen and carbon dioxide). Do not assess intermediate reactions (i.e. no light-dependent and light-independent reactions, Krebs cycle, etc). Focus on the beginning- and end-products of photosynthesis and cellular respiration.
   b) Plants perform both photosynthesis and cellular respiration.

3) All living cells have genetic material (DNA) that carries hereditary information.
   a) The organization of DNA into chromosomes is key to both replication of DNA and its distribution to new cells or organisms.
      i) Differentiate between the terms genome, chromosome, DNA, and gene.
      ii) Describe the chemical and structural properties of DNA (e.g., DNA is a double helix comprised of four different nucleotides).

iii) Explain how base-pairing rules allow cells to replicate DNA molecules.
iv) Recognize that an error in the DNA molecule (mutation) can be transferred during replication.
v) Identify possible external causes (e.g., heat, radiation, certain chemicals) and effects of DNA mutations (e.g., altered proteins which may affect chemical reactions and structural development).

b) Protein structure and function are coded by the DNA molecule.
i) Recognize that DNA codes for proteins, which are expressed as the heritable characteristics of an organism.
ii) Recognize that information flows from DNA to messenger RNA to a resulting protein. (Understanding this concept is more important than the details of transcription and translation.)
iii) Identify the diverse roles proteins play on the cellular level (enzymes, structure, communication, transport, etc.).
iv) Explain how most cells in an organism have the same DNA, genes and chromosomes, but are functionally different because they make different proteins (e.g., pancreatic islet cells make insulin while lymphocytes make antibody).

c) Biotechnology and genetic engineering (e. g., recombinant DNA technology) can be used to analyze or manipulate gene structure and function.

4) The reproductive process provides a genetic basis for the transfer of biological characteristics from one generation to the next.

a) Reproduction can occur asexually or sexually.
i) Distinguish between asexual and sexual reproduction.
ii) Explain the importance of sexual reproduction in the generation of variation among individuals within a population.

b) Chromosomes carry hereditary information from one cell to daughter cells and from parent to offspring during reproduction.
i) Recognize that the reproduction of body cells (and asexual reproduction in single-celled organisms) occurs through the process of mitosis, which results in daughter cells that are genetically identical to the parent cell. Students do not need to name the stages of mitosis or meiosis.
ii) Recognize that through the process of meiosis, the number of chromosomes in gametes is reduced by half. (Emphasize the similarities and differences between mitosis and meiosis, rather than details of the stages involved.).
iii) Explain how fertilization restores the diploid number of chromosomes.

c) The pattern of inheritance for many traits can be predicted using the principles of Mendelian genetics.
i) Recognize that alleles are different versions of a single gene.
ii) Explain the chromosomal differences between human males and females (XY and XX, respectively).
iii) Predict the probability of the occurrence of specific traits, including sex-linked traits, in an offspring by using a monohybrid cross.

5) Structure is related to function in multicellular organisms.

a) The structure of multicellular organisms is best understood as a hierarchy of structural levels from cells, to tissues, to organs, to organ systems, that interact to maintain homeostasis.
    i) Identify the major component parts and explain the function of the primary organ systems of humans, including respiratory, circulatory, reproductive, and digestive systems.
    ii) Provide an example of how different components of the human body interact to maintain homeostasis.
b) Structures in plants and animals support the function of energy transformation.
    i) Relate the operation of body systems to the processes of cellular respiration, nutrient acquisition, and waste removal.
    ii) Relate the major organs of plants (e.g. roots, stems, leaves) to their roles in photosynthesis.

6) A fundamental unity underlies the diversity of all living organisms.
    a) Biological classifications are based on how organisms are related.
        i) Recognize that the probability of relatedness can be determined by comparing DNA sequences.
        ii) Explain how similarities used to group taxa might reflect evolutionary relationships (e.g., similarities in DNA and protein structures, morphology, etc.) with the focus on domains and kingdoms.
    b) The classification of organisms is constantly being revised and extended as scientists gather more information.

III. Evolution and Ecology of Organisms

1) The theory of evolution provides a fundamental framework for understanding the history and diversity of life on Earth and is the central unifying theme of biology.
    a) Evidence for the nature and rates of evolution can be found in anatomical and molecular characteristics of organisms.
        i) Explain the evidence that supports the theory of biological evolution (e.g., fossil records, homologous and vestigial structures, similarities among organisms in DNA/proteins and morphological traits).
        ii) Identify how evolution is happening today (e.g., antibiotic resistant bacteria) and its impact on humans.
        iii) Understand that evolution takes time. Evolution can happen in a few generations, but major change, such as speciation, often requires long periods of time.
    b) Natural selection is one of the primary mechanisms of evolution.
        i) Define evolution as a change in the proportions of alleles in a population. (Note: students do not need to know about Hardy-Weinberg equilibrium.)
        ii) Explain that evolution is the outcome of natural selection: 1) Organisms pass their genetic traits to their offspring. 2) The offspring are not identical to each other, but carry genetic variation as a result of both mutations and new combinations of existing alleles. 3) Not all members of a generation will reproduce equivalently. 4) Because the genetic makeup of the next generation will be derived from those individuals that are able to pass on their alleles, the proportion of individuals with advantageous

characteristics will increase in the population. Note that while mutations occur randomly, the process of natural selection is not random.

iii) Although natural selection can cause a new trait to become widespread, natural selection does not direct the mutations that cause the initial appearance of a trait in the population.

iv) Identify examples of adaptations that have resulted from variations favored by natural selection (e.g., long-eared jack rabbits, camouflaged insects) and describe how that variation provided individuals an advantage for survival.

v) Explain how environmental factors (e.g., habitat loss, climate change, pollution, introduction of nonnative species) can be agents of natural selection.

c) Extinction occurs as a result of both natural processes and human-induced changes in the environment.

i) Explain how genetic homogeneity may cause a population to be more susceptible to extinction (e.g., succumbing to a disease for which there is no natural resistance).

ii) Explain why species that are adapted to a particular environment may go extinct if the environment changes.

2) Organisms interact with one another and with their environment.

a) Interactions among populations within a community affect the structure and balance of an ecosystem.

i) Understand that biologists view the natural world in a hierarchical organization from individuals, populations, communities and ecosystems.

ii) Define a species (e.g. the ability to mate and produce fertile offspring).

iii) Observe a local ecosystem (local pond, aquarium, etc.) and explain the nature of interactions between organisms in predator/prey relationships and different symbiotic relationships (i.e., mutualism, commensalism, parasitism).

iv) Understand the concept of the ecological niche of an organism (the interactions and interdependence of the organism with other organisms and the environment).

b) Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite.

i) Identify and explain the limiting factors (biotic and abiotic) that may affect the carrying capacity of a population within an ecosystem.

ii) Explain how populations within an ecosystem may change in number and/or structure in response to changes in biotic and/or abiotic factors.

c) All organisms, including humans, and their activities cause changes in their environment that affect the ecosystem and the diversity of species within that ecosystem.

i) Explain how natural or human caused changes (biological, chemical and/or physical) in one ecosystem may affect other ecosystems due to natural mechanisms (e.g., global wind patterns, water cycle, ocean currents).

ii) Explain the impact (beneficial or harmful) that a natural or human caused environmental event (e.g., forest fire, flood, volcanic eruption, avalanche, acid rain, global warming, pollution, deforestation, introduction of an exotic species) may have on individuals, populations, species, communities and/or the global environment.

3) Matter recycles within and energy flows through the ecosystem.

a) Matter (e.g., carbon, nitrogen, oxygen) is recycled within an ecosystem.

i) Recognize that living organisms play a critical role in recycling of matter.
ii) Understand that human activities can alter the natural recycling of matter (e.g., global warming).

b) As energy flows through the ecosystem, living organisms capture a portion of that energy and transform it to a form they can use.
i) Illustrate and describe the flow of energy within a food web and an energy pyramid.
ii) Predict how the use and flow of energy may be altered due to changes in a food web.

C. Physical Sciences Entry Competencies

The physical sciences include Astronomy, Chemistry, Geology, and Physics. *College Knowledge: What It Really Takes for Students to Succeed and What We Can Do to Get Them Ready* was used as a resource for the competencies related to these courses. College Knowledge is written by David T. Conley and published by the Center for Education Policy Research in Eugene, Oregon. The competencies also embrace the National Science Standards as expressed in the K-12 standards as adopted by DESE.

A proficient level on Missouri high school science end-of-course exams is desired for all high school graduates; however, these competencies are specific for the introductory classes. The most important skill for success in physical science courses is mathematical proficiency. As mentioned in other places in this report, habits of mind are also very important to achieving that success. Further, students who complete high school chemistry and physics courses should be better prepared to be successful in college level physical science courses. While the competencies below are split into sections according to sub-disciplines within the physical sciences, there is large cross-over between these sub-disciplines such that competencies in one sub-discipline may apply to introductory courses in the others.

I. Geology (Earth Science)

Students should:

1) Be prepared to enter college algebra (see the Mathematics Entry Level Competencies).
2) Know that the earth is a body in space whose environmental system consists of the atmosphere, cryosphere, hydrosphere and biosphere; and that this system depends largely on the sun for light and heat.
3) Understand that the current environment (e.g., geography and climate) has changed dramatically in the past and will continue to do so.
4) Understand that relationships exist among the solid earth (geology and soil science), the water (hydrology and oceanography) and the atmosphere (meteorology and atmospherics.
5) Be aware of the major events in the geologic history of the Earth.

II. Astronomy

Students should:

1) Be prepared to enter college algebra (see the Mathematics Entry Level Competencies).
2) Be familiar with the nature of the solar system and the universe.

3) Be familiar with the basic motions of bodies in space.
4) Have an appreciation of the immensity of the universe.

III. Chemistry

Students should:
1) Be prepared to enter college algebra (see the Mathematics Entry Level Competencies).
2) Understand that atoms, molecules and ions have a set of physical and chemical properties that control their behaviors in a range of states.
3) Know that states of matter depend on molecular arrangement and freedom of motion.
4) Have a basic familiarity with the Periodic Table.
5) Know the structure of an atom.
6) Understand that molecules are composed of atoms in unique and consistent arrangements.
7) Know that substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristics and properties.

IV. Physics

Students should:
1) Be prepared to enter college algebra (see the Mathematics Entry Level Competencies).
2) Understand the relationship between energy, heat and temperature.
3) Understand conservation of mass and energy.
4) Understand the difference between position, velocity and acceleration.
5) Understand Newton's laws as a classical description of motion.
6) Know the characteristic properties of waves.
7) Understand every object exerts gravitational force on every other object.
8) Understand general concepts related to electrical and magnetic forces.